

Superluminal telecommunication: an observable contradiction between quantum entanglement and relativistic causality

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Abstract

I present a schema for a superluminal telecommunication system based on polarization entangled photon pairs. Binary signals can be transmitted at superluminal speed in this system, if entangled photon pairs can really be produced. The existence of the polarization entangled photon pairs is in direct contradiction to the relativistic causality in this telecommunication system. This contradiction implies the impossibility of generating entangled photon pairs.

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Quantum non-locality [1] is a controversial topic of quantum theory. Due to its quantum nature, it is generally believed that the quantum non-local correlation between entangled particles does not produce observable non-local effect, such as superluminal telecommunication, that could contradict the relativistic causality. The schema of the quantum telecommunication is based on the quantum teleportation [2] is often used to justify this affirmation. In that schema a classical channel [3] must be used, therefore no superluminal telecommunication could be realized in such a telecommunication system, in spite of the fact that this system is based on the quantum non-local correlation between entangled photon pairs. As a matter of fact, if one tries to associate binary values to different quantum states, it will be found that it is not possible to encode any information because the result of a measurement is unpredictable, and it is not possible to decode any information because a quantum state can not be determined by a single measurement.

But however, one can encode and decode information in another way. In this letter I present a schema for a telecommunication system using polarization entangled photon pairs as signal carrier in which the superluminal telecommunication can be realized, and the relativistic causality is in direct contradiction with the existence of entangled photon pairs.

The suggested superluminal telecommunication system based on entangled photon pairs is schematically illustrated in Figs. 1, 2 and 3. This system consists of three components: a source of polarization entangled photon pairs, a signal encoder, and a signal decoder. Binary signals are transmitted in this telecommunication system.

During telecommunication processes, polarization entangled photon pairs are generated at the source S. One of the two entangled photons is sent to the signal sender, and the other one is sent to the signal receiver. The signal encoder placed at the signal sender include a mirror (M) which can be switched between the position labeled “0” and the position labeled “1”, and two photon detector channels: the channel “0” and the channel “1”. There are one Glan-Thompson prism and two single photon detectors in each channel. The Glan-Thompson prism (BS_0) in the channel “0” is arranged in such a way that the photons detected by the photon detector D_0 are horizontally polarized, the photons detected by the photon detector D'_0 are vertically polarized. The Glan-Thompson prism (BS_1) in the channel “1” is rotated 45° , so the photons detected by the photon detector D'_1 are polarized at 45° to horizontal direction, and photons detected by the photon detector D_1 are polarized at -45° to horizontal direction.

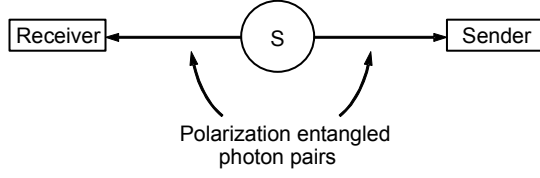


FIG. 1: A schematic show of a superluminal telecommunication based on entangled photon pairs. S is a source of polarization entangled photon pairs

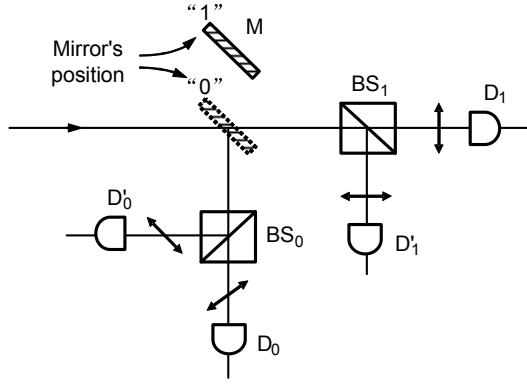


FIG. 2: A schematic illustration of a signal encoder. BS_0 and BS_1 are Glan-Thompson prisms. D_0, D_1, D'_0, D'_1 , are single photon detectors. Polarizations of optical beams are indicated by arrows.

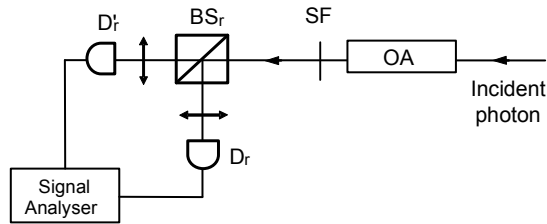


FIG. 3: A schematic illustration of a signal decoder. OA is an optical amplifier. BS_r is a Glan-Thompson prism. D_r, D'_r are single photon detectors. Polarizations of optical beams are indicated by arrows.

The signal receiver is equipped with the signal decoder that includes an optical amplifier (OA), a spatial filter (SF) that allows only photons in the same spatial mode as the incident photon to pass, a Glan-Thompson prism (BS_r) placed at the output end of the optical amplifier which splits an optical beam into horizontally polarized and vertically polarized secondary beams. Two single photon detectors (D_r and D'_r) are placed in each of these two secondary beams. The photon counts by the detectors D_r and D'_r are analysed by the signal analyser, and converted to the signal readout.

When a photon entered in the OA, stimulated and spontaneous emissions both take place. As just one photon is present, the stimulated emitting rate equals the spontaneous emitting rate for photons with the same polarization as the incident photon. At the same time, photons with polarization perpendicular to the polarization incident photon are also generated, at the same spontaneous emitting rate. So the optical beam that passes the spatial filter (SF) contains $2m + 1$ photons with the same polarization as the incident photon, and m photons with perpendicular polarization. In other words, an incident photon is amplified by OA into a partial polarized optical beam. The characteristic of this partial polarized optical beam depends on the polarization of the incident photon.

To send a binary signal “0”, the sender switches the mirror M into the position “0”. In this case the photon sent to the sender can be detected either by D_0 or by D'_0 . Once the photon being detected, the polarization of the photon sent to the receiver is also determined: it must be either horizontally polarized or vertically polarized. The whole system can be setup in such a way that the polarization of the photon sent to the receiver is determined when it arrives at the receiver. This “signal carrier” photon passes the optical amplifier OA, where $2m$ more photons with the same polarization as the “signal carrier” photon and m photon with perpendicular polarization are generated. In the case of sending the signal “0”, $2m + 1$ photons with the same polarization as the “signal carrier” photon are detected by one of the detectors D_r and D'_r , and m photons with perpendicular polarization are detected by another detector. A difference of $m + 1$ in photon counts by the detectors D_r and D'_r corresponds to a binary signal “0” at readout, and the signal “0” is received in this way.

To send a binary signal “1”, the sender switches the mirror M into the position “1”. In this case, in optical beam filtered by SF, $2m+1$ photons are either polarized at 45° or -45° to horizontal direction, m photons are either polarized at -45° or 45° to horizontal direction. Thus each photon can be detected either by the detector D_r or by the detector D'_r with

equal probability. The average photon counts difference is null in this case. A null average photon counts difference corresponds to a binary signal “1” at readout, and the signal “1” is received. Evidently, we must take the photon counts fluctuation into consideration. The signal to noise rate in photon counts is proportional to \sqrt{m} , thus for large m , the signal “0” and signal “1” can be clearly separated.

In the case of the signal “1”, there exist a non-zero probability for finding a difference of photon counts close to $m + 1$. If this happens, then instead the corrected signal “1”, an erroneous signal “0” is read out. Although this error is inevitable, the probability for such an error to happen can be reduced by increasing the amplification of the optical amplifier OA. As a matter of fact, errors happen in any communication systems. In principle, there is no limitation on the number m . By increasing the amplification, one may reduce this “quantum” error rate to be well below other error rates, such as errors related to the detector efficiency that occurs in all telecommunication systems, and make this system as reliable as any classical telecommunication system.

The time τ necessary for transmitting one bit of information depends on the photon detecting processes at the sender and at the receiver. But what is important is the fact that this time τ does not depend on the spatial separation between the sender and the receiver. Thus if the distance between the sender and the receiver is larger than τc , with c the light velocity in vacuum, then the signal transmitted from the sender to the receiver travels at a superluminal speed. In this case, this telecommunication system based on entangled photon pairs becomes a superluminal one.

The transmission of signals at a superluminal speed is in contradiction to the relativistic causality. This telecommunication system that could transmit information at superluminal speeds is based on the polarization entangled photon pairs, therefore the existence of the polarization entangled photon pairs is in direct contradiction to the relativistic causality.

At this point, we are forced to make choice between the possibility of producing quantum entanglement and the correctness of relativistic causality. For most people, the breaking of the relativistic causality is unacceptable. In my point of view, the contradiction between the relativistic causality and existence of quantum entanglement just implies the impossibility of generating entangled quantum states. Many authors consider the photon pairs emitted in a radiative atomic cascade of calcium [4] and photon pairs generated from spontaneous parametric down-conversion [5] (SPDC) as polarization entangled photon pairs. But this

treatment is incorrect. As I pointed out in a recent article, the photon pairs generated from SPDC are in an un-entangled quantum state [6]

$$|\psi_u\rangle = \frac{1}{2}(b_1^\dagger b_1^\dagger + b_2^\dagger b_2^\dagger)|0\rangle, \quad (1)$$

with the positive frequency part of the vector potential in the signal beam given by

$$\vec{A}_s^+ = \frac{B}{\sqrt{2}}(b_1\vec{e}_v - b_2\vec{e}_h)e^{i\vec{k}_s\cdot\vec{r}}, \quad (2)$$

and in the idler beam given by

$$\vec{A}_i^+ = \frac{B}{\sqrt{2}}(b_2\vec{e}_v + b_1\vec{e}_h)e^{i\vec{k}_i\cdot\vec{r}}, \quad (3)$$

where B is a constant, \vec{e}_v, \vec{e}_h are vectors of unit in vertical and, respectively, horizontal directions, and \vec{k}_s, \vec{k}_i are wave vectors for signal beam and idler beam. We have

$$\vec{A}_s^+ \vec{A}_s^+ |\psi_u\rangle \neq 0 \quad \text{and} \quad \vec{A}_i^+ \vec{A}_i^+ |\psi_u\rangle \neq 0. \quad (4)$$

That means for photon pairs in the quantum state $|\psi_u\rangle$, beside the possibility of detecting one photon in each beam, both of the photons can also be detected either in the signal beam or in the idler beam at the same time. The probability of detecting one photon in each beam is only 50% for photon pairs in this quantum state. If the photon pairs generated from SPDC are used in the above described telecommunication system, then the correct information is transmitted only if one and just one of the photon in a photon pair is detected at the sender. But this happens with a probability equal to 50% only. In another word, 50% of the signals received by the receiver are erroneous. Because the correct information can be either “1” or “0”, one can guess the correct information with a probability equal to 50%, without receiving any signal. Therefore an error portion of 50% in signal readouts just means that no information is transmitted, and superluminal telecommunication is not realized. The same conclusion holds also for photon pairs emitted in a radiative atomic cascade of calcium.

In conclusion, I have presented a schema for a telecommunication system based on entangled photon pairs in which superluminal transmission of information can be realized. In this telecommunication system the existence of the polarization entangled photon pairs is in direct contradiction to the relativistic causality. In my opinion, this contradiction just implies the impossibility of generating entangled quantum states.

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